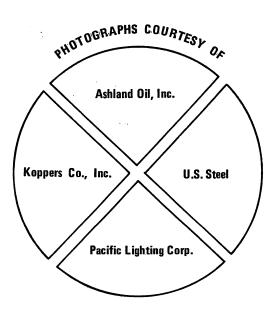


# INDUSTRIAL



### POTENTIAL FOR ENERGY CONSERVATION

IN THE

UNITED STATES: 1974-1978

INDUSTRIAL

A Report of the National Petroleum Council

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September 10, 1974

### NATIONAL PETROLEUM COUNCIL

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Industry Advisory Council to the

U.S. DEPARTMENT OF THE INTERIOR

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### PREFACE

The Industrial Task Group was organized under the National Petroleum Council's Committee on Energy Conservation in November 1973. In response to the charge of the Coordinating Subcommittee, based upon the study request letter from the Secretary of the Interior (see Appendix A), the Industrial Task Group prepared an appraisal of short-term 1974-1978 energy conservation measures applicable to the seven leading energy consuming industries in the United States. The industries evaluated, account for approximately 75 percent of the energy used in the industrial sector. This report represents the detailed work which served as the basis for Chapter Two of the National Petroleum Council's report, Potential for Energy Conservation in the United States: 1974-1978, published September 10, 1974.

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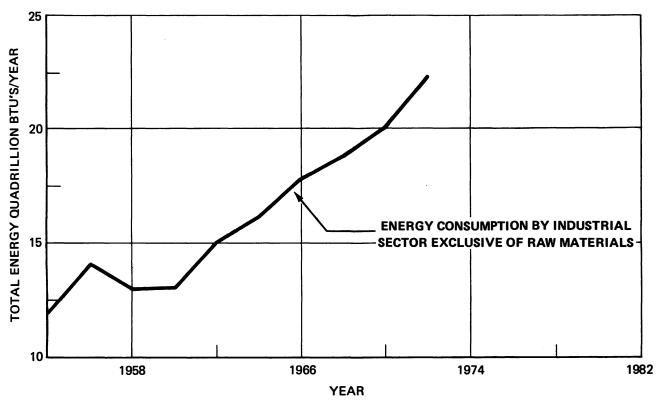
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### INTRODUCTION

The industrial sector is the largest energy consuming sector in the United States. It accounts for approximately 33 percent of the Nation's energy consumption or a total of some 24.3 quadrillion British Thermal Units (BTU's) (equivalent to 12.5 million barrels of oil daily) in 1972.\* Figure 1 shows the historical trend of the industrial sector energy consumption from 1954 to 1972.



Source: National Petroleum Council, U.S. Energy Outlook-An Initial Appraisal (1971-1985), Table 23.

Figure 1. Historical Trend in Energy Consumption by Industrial Sector.

In the past, industry has had limited economic incentives to stress energy efficient processes or equipment because fuel costs have been low relative to capital costs. Even so, many industrial firms have developed and practiced conservation procedures. Since energy costs have increased relative to total manufacturing costs, there are even greater economic incentives for energy management in daily operations. Barring other economic constraints, there will be more incentives for modernizing plants and greater attention will be paid to operating design and practices that will reduce energy consumption.

<sup>\*</sup> This total includes 3.7 quadrillion BTU's for energy products indicated as nonenergy demand-that is, oil, gas and coal and their derivates utilized as feedstocks in the manufacturing of petrochemicals, asphalt, etc.

In order to determine the extent to which industry as a whole could expand its energy conservation techniques, seven industries which account for approximately 75 percent of the energy used in the industrial sector were selected for evaluation. These industries, with their respective energy consumptions in 1972 are:

Industry	Energy Consumed in 1972 (Quadrillion BTU's)
Chemical Iron and Steel	3.5 3.2
Agriculture and Food Processing Petroleum	3.2 3.0
Paper Aluminum	2.2 1.2
Automobile Manufacturing	0.5

In addition, since almost half of the energy consumed by industry is utilized to generate steam, the opportunities for improving the efficiency of industrial boilers and auxiliaries were considered separately.

Qualified representatives from the above industries actively participated in the preparation of this section (see Appendix B for task group rosters).

### SUMMARY AND CONCLUSIONS

### SHORT-TERM CONSERVATION POTENTIAL

The estimated potential savings of energy through conservation efforts by the individual industries through the 1974-1978 period are summarized in Table 1. These figures represent average potentials for the industries and should not be viewed as necessarily applicable to individual companies where past conservation measures may have already effected significant savings. The latter should not be considered as offering additional savings if they were mandated for all companies. While these savings have been evaluated as uniformly as possible, in the final analysis individual judgments based on experience have been necessary, thus creating some uniqueness in each of the industry analyses.

TABLE 1
ESTIMATED CONSERVATION POTENTIAL—INDUSTRIAL SECTOR—1974-1978 (Based On 1972 Energy Consumption)

Industry	Potential Savings Per Unit Of Output (Percent)
Primary Metals (Steel, aluminum, etc.)	5*
Chemicals	20
Petroleum Refining	15
Agriculture	
Farming Food Processing	2 10
Automobile Manufacturing	10
Paper	15
Remaining Industries	_10_
Weighted Average	10

<sup>\*</sup>The 5-percent savings for primary metals is extrapolated from the steel and aluminum projections as these metals make up the primary portion of the primary metals group.

The percentage savings in Table 1 are estimated per unit of output on the basis of 1972 energy consumption, since 1972 was the last year for which final data were available. The industries that were studied in this report consume about 75 percent of the energy consumed by the industrial sector. A percentage savings for the remaining industries was assumed to be 10 percent, so that the weighted average percentage for industry as a whole is calculated to be 10 percent by 1978.

### GENERAL CONSTRAINTS IN INDUSTRIAL SECTOR

The immediate challenge facing industry, government and the public is how best to strike a balance between energy conservation goals and the constraints of limited capital and technical manpower and environmental controls.

# Capital Expenditures

To effect a 10 percent saving of energy per unit of output by 1978, industry as a whole will have to provide capital expenditures of approximately \$1 billion per year. These expenditures probably will be economically justifiable with present and projected energy prices, but they must also compete with other corporate investment projects.

# Availability of Technical Manpower

There is great concern in industry regarding the availability of technical manpower to identify, evaluate and implement energy conservation projects because of a general engineering manpower shortage for normal operations, modernization and expansion. Small companies with limited technical staffs will find it especially difficult to assign the necessary technical effort required to pursue energy conservation projects.

### Environmental Controls

Energy conservation programs frequently conflict with environmental standards because these standards usually necessitate process changes that result in greater use of energy. One example is the reduction in coke production in the steel industry. In order to meet air and water quality standards, it is necessary to increase the use of direct oil injection in blast furnaces. Another example is in the petroleum refining process. The desulfurization of residual fuel oil, to comply with environmental regulations applicable in many areas, requires an equivalent of 3 to 4 percent of the quantity of oil desulfurized as energy for the desulfurization process. In fact, most of the procedures suggested for cleaning up the environment require additional energy.

### PROGRAM FOR ACTION

An effective program for implementing short-term energy conservation in the industrial sector requires action by individual firms. The following are practical steps that a company can take:

• An effective energy management program for an industrial concern must be organized from corporate headquarters down through the individual plants that are involved. The program requires a long-term commitment by top management.

- Special emphasis should be placed on those areas of conservation which represent the greatest potential for savings per unit of capital and managerial effort.
- Realistic goals must be established and employee training and information programs should be initiated.

### **ENERGY MANAGEMENT**

Energy management programs have assumed more vital roles in the plans of industrial firms as a result of the recent sharp increase in energy costs and the threatened scarcity of supply. An effective energy management program requires top management emphasis which must be sustained indefinitely. Realistic objectives should be defined and progress demanded. Management support must be given for effective programs in the form of qualified, aggressive people and adequate funding for operating changes and new investments. The basic requirements for such a program are summarized below:

- An understanding of the basic principles of energy and its use in an industrial plant.
- Comprehensive surveys to determine, quantitatively, where and how energy is used in the plant.
- The application of sound principles of industrial economics to determine the cost of energy usage. (This may not be possible using only accounting cost allocations, as these are tools for internal control and may not give a true picture of energy economics.)
- The establishment of goals, both overall and for specific areas or plants, taking into account the variety of processes involved, e.g., whether batch or continuous, etc.
- Periodic evaluation of results against established goals; this is critical and may involve measuring decreases in losses rather than trying to detect changes in otherwise variable input costs.
- Establishment of training programs for plant operators with special emphasis on energy conservation.
- Enlistment of employee support through in-house education and information programs.

In short, the plan would involve review, analysis, evaluation, and finally, implementation of a permanent program that reflects full corporate dedication.

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### ENERGY CONSERVATION OPPORTUNITIES

The following section contains the individual reports of the seven selected industries plus industrial boilers.

### CHEMICAL INDUSTRY

Utilization of energy products in the chemical industry can be broadly divided into two areas: those used for energy content and those used for carbon and hydrogen content. The latter non-energy categories which are customarily referred to as feedstocks or raw materials are primarily petroleum products and natural gas used by the chemical and allied industries. While such uses currently represent only about 4 percent of total energy use in the United States, these raw materials are derived from the energy sector and are essential to many major industries ranging from agriculture to textiles.

In the past, a great deal of attention has been paid to improving yields of final products per unit of raw materials consumed by the chemical industry. Thus, it is not expected that significant short-term improvements in efficiency in the use of raw materials are likely, relative to, the possible savings of energy in the chemical industry.

# Conservation Emphasis

The following breakdown is representative of how energy is used by the chemical industry, raw materials are not included:\*

Process steam generation	52%
Direct process heat	24%
Purchased electricity   Generated electricity	24%
Total	100%

Process steam usage offers the greatest potential for efficiency improvements. It is also one of the more complex areas, therefore, a complete analysis of a plant's steam system is necessary in order to identify requirements for each item of process or service equip-

<sup>\*</sup> Data from Dow report to FPC National Power Survey Technical Advisory Committee on Conservation of Energy Position Paper No. 17, May 1973.

ment. In addition to the usual attentions paid to reducing leaks, improving controls, setting proper operating conditions, recovering heat, reducing line losses, etc., all of which will reduce energy input; attention should be paid to the overall concept of making more effective use of energy in its unavoidable path of degradation from input level to output level.

Mechanical energy can be recovered from steam by expanding it through turbines from the high-pressure steam production level to the lower-pressure process use level. This mechanical energy can be used directly or can be used to generate electric power. In this way, mechanical energy is produced at a much lower cost than in a large efficient utility steam generating station. The difference is that the utility must reject about two-thirds of the heat absorbed by the boilers to the condenser cooling water. A process industrial plant, on the other hand, can use some or all of this heat by condensing the exhaust steam in the various process heaters. Whenever low-pressure steam is condensed by cooling water or air, roughly 1 thousand BTU's per pound of steam is wasted. Thus, every effort should be made to utilize the energy in low-pressure steam.

The thermal nature of the industrial operation is an important consideration. Many chemical and refining processes are exothermic or have large quantities of high-level heat available for recovery. Frequently, the recoverable waste heat exceeds the amount of energy required for process heating. Good engineering and energy conservation practice calls for this surplus energy to be recovered in the most advantageous way. If the process requires large blocks of mechanical energy, which is often the case, then the solution is to recover waste heat as steam and expand this steam through steam turbines driving the required machinery. In other cases, heat recovery by interchange with other process streams or heat cascading is possible. An example of the latter is to use the heat of condensation from one distillation column to operate a second distillation column which requires a lower-level of heat.

Evaluation of the thermal balance of a given process should pinpoint places where excessive sub-cooling of process streams can occur because of low-cooling water temperatures. If the process stream must subsequently be heated, steam consumption will be increased. Modified operating conditions are normally able to correct this problem.

As the cost of all energy rises and ways are sought to use it more efficiently, consideration should be given to the possibility of siting utility power plants adjacent to industrial plants in order to supply the latter with steam and power. In this way, advantage can be taken of lower investment and operating costs resulting from lower heat rates for by-product power generation while, at the same time, the economic advantages associated with large unit size can be retained. Furthermore, the larger investment required to use more plentiful coal and nuclear energy can be more easily justified.

Process design changes also offer opportunities for energy savings in the chemical industry. Distillation, for example, requires significant amounts of energy usually in the form of steam to the reboilers. By utilizing a scheme known as vapor recompression distillation, overall energy requirements for a given separation can be reduced by 25 to 75 percent. In this process, the overhead vapors are compressed mechanically, elevating their temperature, and then condensed in the reboiler to provide the needed temperature differential to drive the reboiler. The only energy requirements are for the driver on the compressor. Other modifications of distillation processes, such as side-stream draw-off and steam generation on column condenser, may be possible.

# Mechanics of Achieving Energy Conservation

Energy conservation measures may be broadly divided into two categories: those that require capital investment to achieve and those that do not. The latter are achieved by improved operating and maintenance practices, with minimal equipment investment. The potential savings that would require capital investment are believed to range from 50 to 70 percent of the total potential.

As the cost of fuel and power increases, the investment of capital in process equipment to save energy is more readily justified. The extent to which such projects can be justified depends on a number of factors and guidelines established by each company. Figure 2 shows a generalized approach used by one company for evaluating energy savings projects. This figure relates project cost (in thousands of dollars per million BTU's per hour of fuel savings) to cash payout in number of years. A curve is drawn for each assumption regarding fuel cost ranging from \$0.25 to \$2.00 per million BTU's. Calculations were based on continuous usage of 8,533 hours per year, 10 year depreciation, and 50 percent tax rate. For example, a \$150,000 project that will save 10 million BTU's per hour (\$15,000 per million BTU's per hour) would have a cash payout of 3.8 years at a \$0.75 fuel cost.

In general, it is believed that technology could provide a 10 to 15 percent reduction in energy consumption in the chemical industry, assuming constant production rates. Much of the savings would come from improvements in energy systems, such as higher conversion efficiencies, regenerative and recuperative heat recovery and decreased waste. Additional savings might be realized through development of chemical processes that require less energy. In some cases, this may involve reversion to older known processes that might impose other penalties such as lower yield, etc., but would be less energy intensive. Other reductions would require advancements in industrial process technology.

### Short-Term Conservation Potential

Since a large portion of energy consumed by the chemical industry (about 50 percent) is used to generate process steam, con-

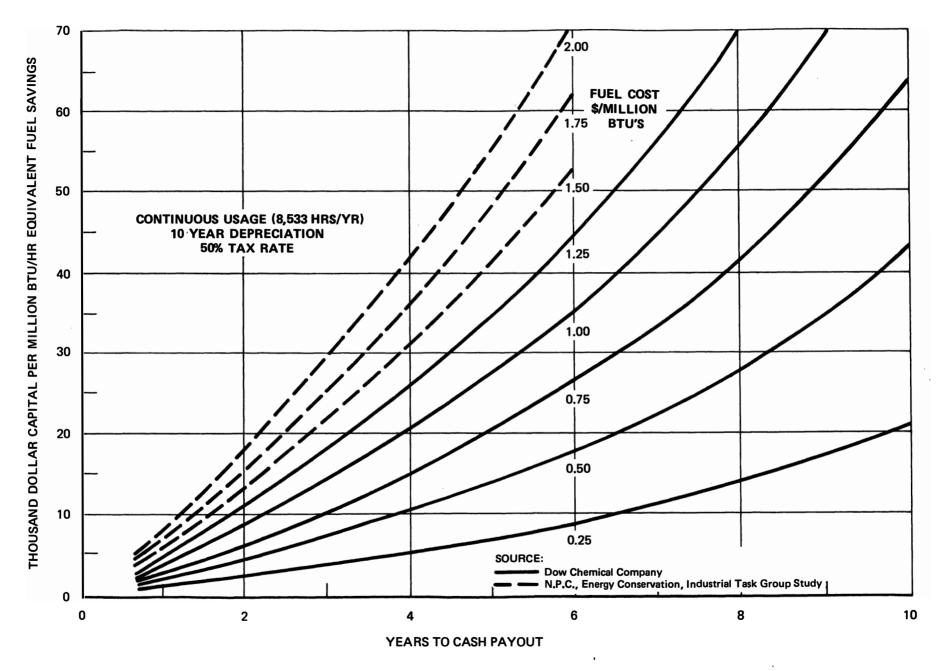


Figure 2. Guidelines for Evaluation of Energy Conservation Projects.

servation of process steam alone provides a potential for significant savings. Other uses of energy, as in direct-fired vessels, also offer opportunities for conservation. Active programs in the chemical industry have demonstrated that substantial savings are possible by application of sound energy management principles. One major chemical company has reduced energy consumption per unit of output by 20 percent in the last two years. Others report similar success as a result of intensive programs. With 1972 demand as a base, it is estimated that a total savings potential of 20 percent is possible by 1978 for the industry.

### IRON AND STEEL INDUSTRY

# Conservation Emphasis

The steel industry in the United States consists of 90 basic steel manufacturing companies and approximately 100 additional firms that purchase semi-finished steel from basic producers for further processing. There are 450 plants throughout the country. In 1973, these companies shipped about 112 million tons of steel products valued at \$25 billion.

Steelmaking processes and energy requirements vary widely from plant to plant. Historically, steel plants have been located to serve a particular market area taking into consideration the availability and cost of transportation, labor, water, scrap, iron ore, coal, natural gas and electricity. The smallest plants are the 100 thousand ton per year mini-mills which use only electricity and natural gas or oil as energy sources. Their process consists of melting scrap in electric arc furnaces followed by casting and rolling. At the other end of the spectrum are the fully integrated mills producing several million tons per year of steel mill products. These plants are based on coal (coke) as a principal energy source.

Figure 3 illustrates the wide difference in energy requirements between an integrated plant producing steel from iron ore and the nonintegrated plant producing steel from recycled scrap. The requirements given in Figure 3 can be misleading. They might seem to indicate that the entire domestic steel industry should initiate plans to convert entirely to a recycled scrap operation; however, the energy consumption figures do not take into account the energy losses associated with the generation and transmission of electric power to the steel mill. If these losses were included, the overall energy requirements of the nonintegrated plant, based on electric melting, would increase to approximately 18 million BTU's per shipped ton.

The 30.8 million BTU's for the integrated plant minus the 18 million BTU's for the nonintegrated plant represents the amount of energy (principally coal) required to reduce 1 ton of iron ore to iron. All present methods of iron ore reduction require 12 to 15 million BTU's of energy per ton of iron produced. But the reduction of iron ore cannot be avoided because there is not enough

### **NONINTEGRATED PLANT INTEGRATED PLANT** ENERGY BTU X 106 ENERGY BTU X 106 COAL **LIMESTONE** 27.8 COKE (5.0)\***OVENS BLAST** IRON ORE-**FURNACE PURCHASED SCRAP RECYCLE** RECYCLE **SCRAP SCRAP ELECTRIC BASIC** 0.1 3.2 **OXYGEN** ARC **FURNACES FURNACES INGOT INGOT** 0.4 0.4 **CASTING CASTING** HOT HOT 5.5 5.5 **MILLS MILLS**

\* Credit for coke oven gas, coal tar, and coal chemicals either used or sold.

*OF SHIPMENTS* ---- 30.8

**PROCESSING** 

**FACILITIES** 

1 NET TON

OF STEEL PRODUCTS

TOTAL ENERGY PER NET TON

Figure 3. Examples of Energy Requirements for Integrated and Nonintegrated Steel Plants.

**PROCESSING** 

**FACILITIES** 

1 NET TON OF STEEL

**PRODUCTS** 

2.0

---- 11.1

2.0

scrap or electricity available in the United States to permit this type of operation for all of the domestic steel requirements.

In addition to variations in processes, there are variations in end products. Hot rolled products (reinforcing bar, structurals, etc.) require less total energy to produce than cold rolled, heat treated or coated products. Serious errors would also result from applying industry averages to the steel operations in different regions of the country. It is readily apparent, therefore, that industry averages cannot be used to describe an individual steel plant.

# Mechanics of Achieving Energy Conservation

Natural gas prices, especially in the northeastern section of the United States have favored the use of fuel conservation devices in steel plants. Some examples of conservation measures are:

- Recuperators and air preheaters
- Waste heat boilers
- Automatic combustion controls
- Insulated water cooled members in reheating furnaces
- By-product utilization.

The first two measures are of particular interest because they apply to a large segment of the industry.

The two main methods for recovering heat from flue gases exiting from high-temperature furnaces are: (1) recuperators to use the flue gases to preheat combustion air and (2) waste heat boilers to use the heat of the flue gases to generate steam. The preheating of combustion air affords a sizable reduction in fuel consumption, but a more efficient recovery of waste heat from flue gas can be accomplished with waste heat boilers. This latter recovery method has a potential thermal efficiency of approximately 80 percent compared to 60 percent for recuperators. For this conservation method to be effective, there must be an economic use for the steam generated. Furthermore, an alternative heat capability must be installed in most cases because the generation of steam will follow the pattern of furnace operation rather than the pattern of steam demand.

As Table 2 indicates, conservation efforts should be concentrated in different areas for integrated and nonintegrated plants. The major objective in the integrated plant should be the collection and more efficient use of the by-product fuels generated by coke ovens and blast furnaces. Additional heat recovery devices and improved efficiences would lower the purchased fuel requirement.

### TABLE 2

# SOURCES OF ENERGY FOR STEELMAKING (Percent)

	Average of Integrated Companies*	Average of Nonintegrated Companies	Average of All Companies
Coal	70.0	7.1	68.9
Natural Gas	19.8	63.2	20.6
Fuel Oil	6.6	6.0	6.5
Electricity	3.6	23.7	4.0
Total	100.0	100.0	100.0

Source: A 1972 industry-wide survey by the American Iron and Steel Institute (AISI). \*Includes both integrated and nonintegrated plants operated by these companies.

In the case of the nonintegrated plant, the major target for conservation is the consumption of natural gas and/or fuel oil used by the hot mill reheating furnaces. Waste heat recovery and improved surveillance by plant personnel is the key to conservation. Electricity is also a major energy source for electric furnace steelmaking and rolling mill drives. Consequently, demand control and power factor correction are important in the nonintegrated plant. Typical fuel usages that need study are:

- Process heat
  - -- Reheat furnaces prior to hot rolling
  - --Heat treating
  - --Coating
  - -- Soaking pits
  - --Annealing
  - --Atmosphere gas generation
  - --Calcining
  - --Sintering
  - -- Transportation
  - --Space heating
- Steam
  - --Space heating
  - --Turbine drives
  - --Coating weight control
  - -- Indirect heating -- pickle tanks
  - --Oil atomization
  - --Vacuum systems for degassing
- Purchased and generated electricity
  - --All rolling and processing operations
  - --Heat treating
  - -- Material movement
  - --Lighting, etc.

- --Pumps, air compressors, fans, etc.
  --Electric furnaces (induction, arc, resistance)
- By-products used as fuel
  - --Coke oven gas
  - --Blast furnace gas
  - --Coke oven tar
  - --Waste oil

# Recycling of Steel Scrap

The most important area of energy conservation in the iron and steel industry is in the recycling of scrap steel which accounts for about 46 percent of raw steel production. As mentioned earlier, the electric furnace recycling of a 100 percent steel scrap charge consumes approximately 13 million BTU's less energy per ton, than the process of reducing iron ore. However, recycling is limited by shortages of scrap and electric power.

Historically, the steel industry has tried to strike an economic balance between the two processes. Integrated plants with iron ore reducing blast furnaces also depend on supplementing pig iron with scrap charges in steel producing furnaces, such as open hearth and basic oxygen furnaces. Open hearths are relatively flexible; they can operate with as little as 25 percent scrap or as much as a 65 percent scrap. Basic oxygen furnaces operate on a thermal balance of approximately 25 to 30 percent scrap and 70 to 75 percent pig iron. About 60 percent of industry's total scrap requirements are generated and recycled within the steel plants.

In recent years, both domestic and foreign steel industries have been operating at capacity levels. Much of the U.S. scrap has been exported to other countries. Table 3 shows the U.S. steel industry's scrap consumption, in-plant scrap generation, purchases and exports for a 4 year period including projections for 1974. Ferrous scrap requirements for the foundry industry are not included.

It is evident that an increasing percentage of available domestic scrap has been exported during the period of cost/price controls and high energy costs. Industry has been forced to reduce inventories to dangerously low levels. Reclaimed scrap that normally would be brought into the market in 1974 may have already been collected, sold, and possibly exported in 1973 so the available scrap in 1974 may be less than normal.

The domestic energy supply outlook indicates that the exportation of energy-containing scrap may be unwise because it has the effect of greatly increasing energy requirements to reduce additional iron ore. The 11.2 million tons of scrap exported in 1973 represents the export of approximately 150 trillion BTU's or the energy equivalent of 24 million barrels of fuel oil.

The present policy of the government will permit the export of at least 8.4 million tons of scrap in 1974. This represents at

#### TABLE 3 STEEL INDUSTRY SCRAP CONSUMPTION, IN-PLANT SCRAP **GENERATION, PURCHASES AND EXPORTS—1971-1974** (Millions of Tons) 1972 1974 1971 1973 133.2 150.5 Raw steel production 120.4 150.0 85.0 64.6 73.4 81.2 Scrap consumption 44.4 50.4 48.0 42.5 In-plant scrap +1.0 -.4 -1.0+.7 Inventory change 29.8 38.0 22.8 28.5 Purchased scrap 7.4 11.2 Exported scrap 6.5 Total scrap sold 40.7 49.2 54.6 15.9 15.0 20.6 Percent exported

least the energy equivalent of 18 million barrels of residual oil or 50 thousand barrels per day. On the other hand, the side effects of reduction of scrap exports on balance of payments and international trade relations must be considered.

### Short-Term Conservation Potential

Sixty-eight and nine-tenths (68.9) percent of the energy consumption of the basic steel industry was supplied in the form of coal or coal by-products in 1972. Short-term opportunities for reducing this energy requirement are limited.

Approximately 70 percent of the industry coal requirements are supplied by captive mines. Any reduction in the supply of coal (coke) is almost immediately reflected in a decrease in production of pig iron by the industry's blast furnaces and a resulting reduction in steel shipments. Except for a very limited number of gasfired direct reduction units, the industry is dependent on the energy from coke for the reduction of iron ore. Integrated companies (those with blast furnaces) produced 87 percent of the raw steel production in 1972.

The 27.1 percent of total energy in the forms of natural gas and petroleum is almost an irreducible minimum for downstream processing units (annealing, heat treating, coating lines, etc.) where there is no known technology to substitute coal as the energy source. (The 27.1 percent requirement takes into account usage of all coke making by-product fuel and is a net requirement.)

It is interesting to note that in most industries, other than steel, approximately 50 percent of the energy usage is required to produce process steam. In contrast, one major steel producer consumed only 16.9 percent of its total energy usage in the production of all steam. This is thought to be typical of the entire industry.

While other industries may have the opportunity to show significant energy savings as the result of conserving process steam, this is not possible for the steel industry.

Since steel is highly dependent on coal for energy and coal is the Nation's most abundant energy source, most of the industry's conservation efforts will be directed initially toward conserving the other forms of energy; namely, natural gas and petroleum products. Where economically feasible, fuel savings will be achieved by greater utilization of waste gas recuperators, altered operating schedules, improved combustion efficiency, higher utilization of waste process heat and improved blast furnace practice.

With 1972 energy usage as a base period, the industry estimates that a 5 percent reduction in energy usage per unit of output can be accomplished by 1978. This assumes that operating rates will remain high so as to take advantage of the efficiencies of greater equipment utilization.

AGRICULTURE AND FOOD PROCESSING

### Agriculture

Agriculture and food processing energy usage accounts for 12 percent of the total U.S. industrial energy consumption, or approximately 3.2 quadrillion BTU's annually. Energy consumption on the farm is about 30 percent of total agriculture and food processing industries' usage, or equivalent to approximately 1 quadrillion BTU's annually.

Ostensibly, one farmer in the United States now provides food and fiber for approximately 51 people. In reality, approximately two support workers are required for each farmer, since farm food production must generally be further processed to some degree. These food processing and associated operations consume large amounts of energy and, therefore, overall energy requirements are several times those used in crop production.

As recently as 1920, animals provided about 25 million horse-power of energy to the agriculture industry. Such animals, primarily horses and mules, required one-fourth of the harvested crop acreage for feed. If U.S. farmers were to get their horsepower from animals today, they would require over 80 million acres (25 percent of currently cultivated land) just to supply the animal feed. Thus, the use of tractors and other machines, powered directly or indirectly by fossil fuels, has freed a substantial amount of cultivable land to produce food for humans and has greatly changed the patterns of energy requirements. The replacement of human energy by mechanical power since 1920 is shown in Table 4.

Short-range conservation can be achieved best through intensive educational and training programs. The major difficulty in such a program is in the logistics of supplying information to the millions of individual farmers. (There are some 2.8 million farms

### TABLE 4

### PRODUCTION OF UNITED STATES CROPS— LABOR VERSUS MECHANICAL POWER

	Tractor Horsepower (Millions)	Labor Farm Work, Hours (Millions)
1920	5	13,406
1950	93	6,922
1960	153	4,590
1970	203	3,209
1972	209	3,170

Source: Economic Research Service, Department of Agriculture, Changes in Farm Production and Efficiency: A Summary Report, June 1973.

in the United States.) Procedures do exist, however, to disseminate information through federal and state agricultural agencies and extension services, universities and agricultural associations, and many actions have already been initiated.

Some of the longer-term potentials for energy savings are listed in the following. The means or techniques to achieve most of these savings have not been established nor have the economics been evaluated.\*

- Development of more efficient and better yielding crops.
- Optimization of the minimum use of chemical fertilizers with maximum use of manure and farm by-products.
- Use of "no tillage" or minimum tillage for land preparation and crops where practical.
- Development of crops that are more resistant to insects, disease and birds, thus reducing energy inputs of pesticides and other chemicals.
- Production of specific crops only in regions that give maximum yields per unit of energy input.
- Use of natural field drying to the maximum extent possible.

<sup>\*</sup> Farm equipment utilization and operation are considered in the report by the Transportation Task Group.

### Food Processing

Over three-fourths of the food produced by agriculture is commercially processed before its final use. Processed food may be consumed by other industries, sold to other producers, or delivered to the consumer.

The energy consumed in food processing is not accurately known, although estimates indicate that it may be about 2.2 quadrillion BTU's annually--about two times the energy consumed on the farm. The processes that use the most energy are cooking/sterilization, grinding and milling, mechanical handling, washing and cleaning, refrigeration, drying and evaporation, sanitation, packaging, and by-product and waste treatment. The food categories that use the most energy are meat products, fluid milk, bakery products and beverages.

Practically all food processing companies have already initiated both short- and long-term energy conservation programs. The short-term measures rely primarily on energy management and employee education programs. The significant long-range savings in the food processing industries are likely to result from the following measures:

- Utilization of wastes and by-products instead of disposal (e.g., nutshells, fruit pits)
- Less packaging of foods with more bulk handling\*
- Education of consumers regarding energy efficient foods.

Food processing is an essential industry. Recent highly publicized cases of food toxicity and contamination have resulted in increased cooking and sterilization requiring increased energy consumption rather than reductions. Health and nutrition must always receive priority consideration in energy allocation.

# Cooking/Sterilization and Refrigeration

A major limitation to energy conservation in the food processing industry is the need to assure the safety of humans and animals. Cooking/sterilization and refrigeration are two energy-intensive steps in food processing, consuming an estimated 15 to 20 percent and 20 to 25 percent, respectively, of total food processing energy. An adequate amount of treatment is essential in order to provide nutritious and safe products, and it is possible that more protection is needed than is now employed. Practically all food products

<sup>\*</sup> Production of packaging materials has not been included as part of food processing; however, packaging has become one of the larger consumers of energy--from raw materials to solid waste disposal.

contain large amounts of moisture and are thus subject to spoilage. Even most cooked/sterilized products must be canned or kept refrigerated. Conservation opportunities do exist in these operations, but the operations themselves must not be omitted under current technology. Improvements in food handling and processing equipment operations offer the most promising opportunities for short-range energy conservation.

# Field Drying

Similar risks are involved in the natural drying of agricultural products in the field. Although fuel can be conserved by allowing harvested products to dry longer naturally, the danger of formation of natural toxins which could contaminate edible food products is real. In addition, there is sometimes a sizable loss in yield due to extended exposure of products to the natural elements.

### Short-Term Conservation Potential

### Agriculture

Energy usage on-the-farm for agriculture is equivalent to approximately 1 quadrillion BTU's annually or about 4 percent of the total 1972 U.S. industrial energy consumption. Most of this energy is received in the form of gasoline, diesel fuel and liquefied petroleum gas fuel--all derived from petroleum and natural gas. World requirements for more and safer foods have resulted in increased onthe-farm energy consumption. This situation is expected to continue indefinitely. In addition, energy requirements are subject to natural weather conditions and emergencies and may experience major seasonal variations from the averages.

Short-range conservation can best be achieved through intensive education and training programs. The major difficulty lies in disseminating information to the millions of individual farmers on some 2.8 million farms in the United States. It is belived that additional energy savings can be accomplished through the existing federal and state agricultural agencies and extension services, universities, and agricultural associations. In the short term, only a 2 percent savings per unit of output through conservation is anticipated, which would amount to about 20 trillion BTU's in 1972-equivalent to 10 thousand barrels of oil daily.

# Food Processing

Practically all food processing industries have expanded their energy conservation programs. Short-term measures rely primarily on energy management and employee education programs. An overall energy savings rate of about 5 percent per unit of output (based on the 1972 ratio) was achieved by the end of year 1973 and an additional 5 percent savings is expected by the end of year 1974.

These savings require minimal processing changes and capital investment.

There are further opportunities for significant short-term energy reductions. Most of these require revised processing techniques, energy recovery systems, processing controls, and even some different food products. Most require capital expenditures. In total, savings of 10 to 15 percent per unit of output are expected by 1978, equivalent to 220 to 330 trillion BTU's per year or about 105 to 150 thousand barrels of oil daily.

### PETROLEUM REFINING

In petroleum refining, three principal areas of opportunity exist for increasing energy use efficiency. These areas involve recovering energy of the following types:

- Thermal --waste heat recoverable from hot process streams, flue gas, and exhaust steam
- Chemical --heat obtainable from the combustion of fuels and from exothermic reactions such as hydrogenation, polymerization, etc.
- Hydraulic--that which can be obtained from high-pressure process streams.

### Conservation Emphasis

Refineries vary as to capacity, complexity, type of processing equipment and product slate. Table 5 shows a typical refinery subdivided into the various process units and the energy consumed in each process. This typical refinery consumes about 1 barrel of fuel for every 10 barrels of crude oil processed or an energy equivalent of 600 thousand BTU's for processing 1 barrel of crude oil.

It can be seen from Table 5 that the cracking unit is the major energy consumer in a refinery and thus, the unit which deserves maximum attention with respect to conservation. Crude units and reformers are also substantial users of energy.

Energy consumption in a refinery can be segregated into three distinct areas--process heat, steam generation and electricity. A typical gasoline manufacturing refinery has the following energy breakdowns:

Process heat	60%
Steam generation	25%
Electricity	15%
Total	$\overline{100}$ %

From the above percentages, it can be seen that energy being consumed as process heat (fuel to furnaces) is a primary target.

TABLE 5
ENERGY EXPENDED IN A TYPICAL U.S. REFINERY

Refinery Process	BTU's Consumed (BTU/Bbl Crude)	Main Areas for Energy Recovery
Crude	140,000	Air preheaters, hydraulic turbines, cleaner and more heat exchangers
Cracking	195,000	Flue gas expanders, by-product gas expanders, improved regeneration, waste heat recovery
Reforming	75,000	Air preheaters, waste heat boilers, regen heat recovery systems
Alkylation	45,000	
Asphalt	20,000	Recover heat from oxidation
Coking	15,000	Air preheaters
Oil Movement	10,000	
Other (Motor oils, chemicals, utilities)	100,000	
Total .	600,000	

# Mechanics of Achieving Energy Conservation

Although the refining industry has attempted to optimize energy conservation investments based on economic conditions of the past, there is room for further progress in a new environment of higher energy costs. As in other industries, the opportunities will be found in three basic areas:

- Better management and utilization of existing facilities.
- Capital investment to achieve energy savings.
- Improvements in technology.

# Energy Conservation with Existing Facilities

Some of the important areas for conservation opportunities (without significant capital investment) are:

- Operation of process heaters; reduction of excess air by closer operator surveillance and heater efficiency improvement programs.
- Cutting off heating tanks and lines (out-of-season asphalt tanks, etc.) except when needed.
- Minimization of reflux ratios in fractionating towers.

- Greater bypassing of intermediate storage with unfinished refinery intermediates (hot run-down from one unit to the next).
- Use of antifoulant materials in heaters and exchangers.
- Minimization of lean oil and sponge oil circulation rates.
- Use of steam stripping (at minimization rates) rather than reboiling where practical.
- Closer control of hydrogen recycle rates in hydrodesulfurization and cat-reforming units.
- Optimization of cooling water circulation.
- Maintenance of high vacuum on steam condensers for maximum power recovery by eliminating leaks and maintaining ejectors and condensers.
- Capture of hydrocarbon now lost to flares and vents.
- Optimization of operating pressures in process units.
- Proper maintenance of steam-distribution systems including insulation, traps, valve packing, etc.

# Capital Investments for Energy Conservation

Most refinery equipment was designed and installed during periods of low energy cost. The current and projected higher energy costs provide substantial incentives for replacement of existing equipment with more efficient equipment that could conserve energy in the following ways:

- Installation of air preheaters, waste heat boilers or additional economizer sections in process heaters.
- Redesign of heat exchange systems.
- Installation of exchanger bypasses to facilitate on-stream cleaning.
- Collection of condensate for reuse.
- Recovery of power from cat-cracker flue gas and high-pressure liquid streams in hydrodesulfurizer units.
- Recovery of heat from catalyst regeneration in fluid catalytic cracking.
- Design of system pressure drops to optimize pumping or compression power requirements.

### Improvements in Technology

Technological advances are needed for further reductions in energy usage. These savings will not be achieved in the short run, but it is imperative that work be started soon. Some potential areas for research and development are:

- Recovery of low-level heat
- Development of cold separation processes
- Introduction of nuclear heat for processing
- Improvement in catalysts for temperature and pressure reductions.

### Short-Term Conservation Potential

Energy savings within existing refining facilities can be obtained without significant capital inputs but by means of surveillance and maintenance of operations. It is estimated that more than a 5 percent saving in total fuel used could be realized by an average refinery and much more by refineries that have neglected energy conservation measures. Energy savings by capital investment will take longer to achieve but the potential benefits will be greater--possibly 10 to 15 percent by 1978.

### PULP, PAPER AND PAPERBOARD INDUSTRY

The U.S. pulp, paper and paperboard industry consists of almost 6 thousand plants in 49 states. It produced 62 million tons of paper and paperboard in 1973. The industry is the fourth ranking manufacturing consumer of energy in the Nation, with a total use of 2.2 quadrillion BTU's in 1972, according to a recent survey by the American Paper Institute (API). It ranks first among manufacturing consumers of fuel oils at about 70 million barrels per year.\*

Energy requirements of different paper products vary widely. While the manufacture of a short ton of newsprint may utilize only some 15 million BTU's, fine book and writing paper grades use up to 48 million BTU's. The range is even greater when certain grades of construction board and specialty papers are considered.

# Conservation Emphasis

# Recycling

Energy conservation through the increased use of recycled raw materials has become a topic of widespread interest. While there

<sup>\* 1972</sup> Census of Manufactures, Bulletin #MC72(SR)-6

appear to be a number of manufacturing industries which could reduce their purchased energy consumption in this way, this may not be the case for the pulp and paper industry where secondary fibers now contribute about 23 percent. Although it is true that a given unit of paper product made from recycled fiber may require less energy than an equivalent unit made from primary wood fiber, the primary fiber operations obtain a large proportion of their energy from their own process wastes, such as spent pulping liquor and bark. A typical kraft linerboard mill, for example, obtains some 50 percent of its energy requirements from these sources. Some of the newer mills obtain upwards of 75 percent.

Recent American Paper Institute surveys of energy consumption in the pulp and paper industry have shown that the energy required in plants manufacturing recycled paperboard averaged 19.4 million BTU's per short ton, compared with an average of 29.5 million BTU's per short ton for primary linerboard mills. But since about 50 percent of the energy consumed in the primary mills was generated from process wastes, the net energy demand from purchased fossil fuels averaged only 14.8 million BTU's per short ton. In light of these data, it would appear that while primary fiber production requires more total energy, it makes less of a demand on fossil-fuel supply than secondary fiber.

# Fuel and Energy Applications

The pulp and paper industry utilizes fuel and power in the form of electricity, steam and direct heat for drying. Figure 4 is a diagram of a typical kraft paper mill (refer to figure for number references).

Electricity is used in the following processes:

- (1) <u>Barking</u>--as the pulpwood enters the mill, revolving bark-ing drums remove the bark.
- (2) <u>Chipping</u>--the debarked pulpwood is mechanically chipped into small pieces, which then go to the digester, where the fibers are separated. (<u>Grinding</u>--where groundwood pulp is required the debarked pulpwood is mechanically ground to separate the fibers.)
- (9) <u>Paper Machine</u>--fiber, passing over screens and through presses, is made into paper.

Steam is used in the following processes:

- (3) <u>Digester</u>--wood chips, straw, cotton and other fibrous materials are mixed with chemicals and steam heat is applied to separate the fibers and produce pulp.
- (4) <u>Washing</u>--the lignin and pulping chemicals are separated from fibers.

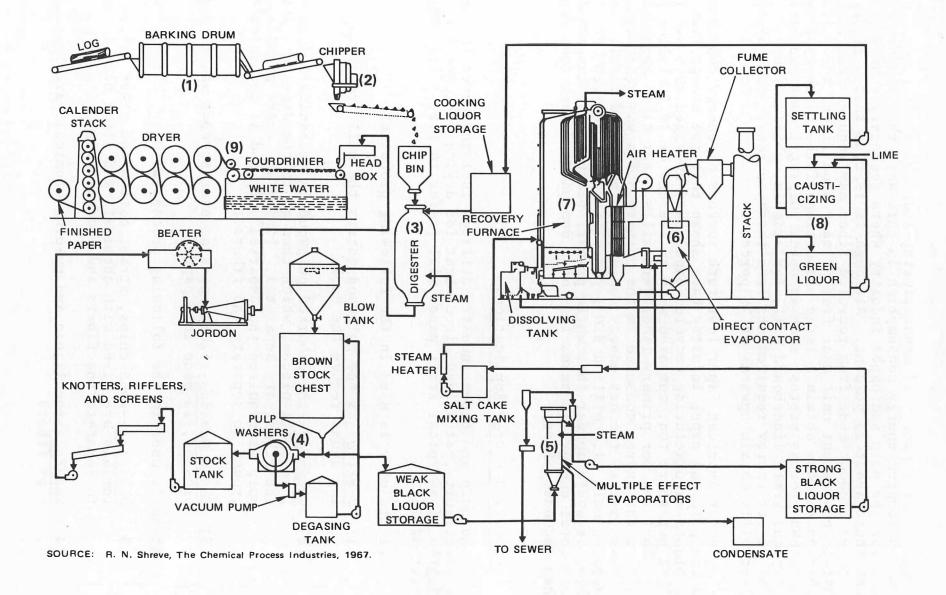


Figure 4. Kraft Paper Manufacturing Processes.

- (5,6) <u>Evaporation</u>— water is removed from weak spent pulping liquor so that it can be burned.
  - (7) <u>Recovery Plant</u>--pulping chemicals are removed from the spent pulping liquors. These chemicals are reused for fiber separation.
  - (8) <u>Recausticizing</u>--reformation of the lime used in chemical recovery.
- (9) Paper Machine -- steam is used to dry the paper.

Finally, direct heat is also used in the flash drying of paper.

# Mechanics of Energy Conservation

There are many energy saving approaches which are applicable throughout the process industries, those which apply to the pulp and paper industry alone are:

- Improvement of techniques and practices which decrease broke (unusable paper), minimization of grade changes on the papermaking machines, and increase pulp yields.
- Avoidance of overdrying paper. A 1 percent decrease in moisture content at the dry end of the paper machine can require almost 3 percent more steam.
- Increased effectiveness of the press section. A 1 percent average decrease in moisture delivered to the dryers by the press section can be achieved by various control methods and/or press improvements. Because moisture level is of the order of 60 percent at this point, net steam savings is upwards of 5 percent of the steam used in the dryers.
- Use of hot exhaust air from gas turbines for paper drying.
- Increased use of wood refuse and other solid wastes as fuels.
- Improvement of water pollution abatement procedures. This can mean substantial savings of heat if approached via reduction of fresh water usage through recycling and can achieve plantwide steam savings of up to 10 percent.
- Improvement of process ventilation methods. For example, the closed paper machine hood achieves a 5 to 10 percent steam saving by using less air to vent the evaporated moisture. In cold climates, the elevated temperatures which result from closing the hood present opportunity for less heat reclamation by economizers and result in even greater savings.

# Short-Term Conservation Potential

The Raw Materials and Energy Division of the API, in cooperation with the Technical Association of the Pulp and Paper Industry

(TAPPI), formed a Committee for the Conservation of Energy early in 1973. In October of that year, the Committee published a pamphlet entitled 21 Ways to Save Energy, which listed energy saving steps and cited a 7 percent reduction in total energy consumption per unit of output as a reasonable goal for most pulp and paper mills.

Since the Arab oil embargo was initiated in October 1973, many companies have reported achieving savings of from 10 to 12 percent in purchased energy consumed per ton of output. With additional capital investments, some companies in the industry may be able to reach savings of 20 to 25 percent by 1978. However, for the industry as a whole, potential savings of 15 percent per unit of output are projected.

One important aspect of the reported reductions in purchased energy requirements is the implication for energy obtained from the paper industry's own process wastes. While this source of energy was projected to meet 39.1 percent of the industry's total energy requirements in 1976, the significant reduction in purchased energy consumed may mean that this proportion has already been reached. With further conservation of purchased fuels, the relative energy contribution of process wastes will increase still further.

#### ALUMINUM INDUSTRY

# Conservation Emphasis

Aluminum production is highly energy intensive. Basic operations within the aluminum industry consist of mining, refining, smelting and mill products fabrication. However, since much of the bauxite mining is conducted outside of the United States, and does not offer domestic energy conservation potential, this phase of the industry's operations has not been included in the analysis.

Natural gas, propane, fuel oil, electricity, coal and gasoline are used in production plants with natural gas the major nonelectric source of energy. Excluding electric power for smelting, natural gas (on a BTU-basis) represents over 75 percent of the energy consumed. Estimated distribution of energy consumption by basic operation is shown below:

	Nonelectrical Energy (BTU-Basis)	Electrical Energy (KWH-Basis)
Refining Smelting Mill Products Fabrication	55% 25% 20%	5 % 9 0 % 5 %
Total	100%	100%

Refining operations use process steam and process heat for refining and fabricating plants by eliminating unnecessary lighting.

Also, improvements in operating schedules and shut downs of electric motors when not required have resulted in reduced electric power consumption.

# Mechanics of Energy Conservation

Individual companies in the aluminum industry have committed top management and technical personnel and major financial resources to energy conservation. Specific objectives have been set for energy conservation programs with special emphasis placed on fuels used for process heat and steam generation. By-products are utilized wherever possible, as in the case of reclaiming and reusing of rolling oil and other oils and lubricants.

A considerable amount of energy is being conserved by improved operation, surveillance and maintenance of existing plants and offices. Electrical consumption has been reduced by lowering illumination levels. Space comfort conditioning energy requirements have been reduced by lowering or raising thermostat settings in the heating or cooling seasons. Intensified communication programs have stimulated employee participation practices which have extended beyond the job to increased use of car-pooling.

Large capital expenditures have been made in major efforts to achieve significant energy savings. Examples of these efforts include:

- Installation of flash calcining equipment to replace less energy efficient conventional calciners.
- Recovery, processing and reuse of rolling oil and other oils and lubricants.
- Replacement of mercury-arc rectifiers with silicon diode rectifiers.
- Installation of air curtain dampers on melting furnaces.
- Improvement of thermal efficiency of melting furnaces by better furnace design coupled with preheating combustion air and products to be melted.
- Installation of equipment to produce nitrogen from the atmosphere to conserve natural gas used to fire inert atmosphere generators.
- Conversion of process furnaces and steam boilers from gas to oil. (Design usually precludes conversion to coal.)
- Utilization of exhaust waste heat from existing furnaces for space heating or other process uses.

# Recycling of Aluminum Scrap

Recycled aluminum scrap has been an important material supply source and it has provided significant energy saving because aluminum can be recycled to the molten state for only 5 percent as much energy as it takes to make virgin aluminum. The scrap can be recycled an indefinite number of times.

Recovery of new scrap and old scrap over the past decade has been about 22 percent of domestic ingot supply, varying both above and below this average. In 1972, approximately 1.173 million tons of metal were recovered from scrap, or 19.4 percent of the total U.S. supply of 6.056 million tons. Preliminary data for 1973 indicate that 1.186 million tons were recovered--about 16.9 percent of total supply of 7.023 million tons. The lower percentage in 1973 was caused principally by the release of 730 thousand tons of aluminum ingot from the strategic stockpile. Excluding the supply from stockpile, secondary recovery amounted to about 19 percent of total normal supply.\*

New scrap forms the larger portion of secondary recovery; it is closely related to the volume of shipments of mill products and castings to plants making end products of aluminum. Old scrap is recovered from metal that has been used by consumers, and the availability of such scrap depends upon varying life-cycles of products using aluminum--from beverage cans with life-cycles of only a few months to building applications with life-cycles of scores of years. For example, an estimated 1.6 billion all-aluminum cans were returned to recycling centers throughout the U.S. in 1973. This represents a record 68 million pounds of cans--an increase of 28 percent over the 53 million pounds of all-aluminum cans reclaimed in 1973. All together, 1 out of 7 all-aluminum cans purchased by consumers in 1973 were reclaimed.

### Short Term Conservation Potential

Approximately two-thirds of the total energy consumed by the aluminum industry is represented by electric power and carbon products used in the smelting process. While small electrical savings can be realized by changing rectifier equipment, major power reductions from new smelters are not expected until late in the 1974-1978 period or beyond. Carbon products used for anodes and cathodes in the electrolytic smelting process offer limited opportunities for energy savings. Almost all energy savings will continue to result from conservation of fossil fuels used for steam generation, and process and space heat. Based on total energy consumed per unit of production during 1972, the aluminum industry should realize a 5 percent savings in total energy in 1978.

<sup>\*</sup> The 1972 and 1973 figures are from the U.S. Bureau of Mines and are exclusive of "run-around" scrap consumed by producers and semi-fabricators in the aluminum industry. It is believed that the Bureau of Mines data probably understate "real" recovery by about 10 percent.

### AUTOMOBILE MANUFACTURING

Energy consumption by U.S. automobile manufacturers totals approximately one-half quadrillion BTU's per year, or 2 percent of total direct industrial energy consumption. Although this is an order of magnitude smaller than the other industries evaluated here, it represents a form of energy usage that can be easily related to other manufacturing or fabricating industries, such as appliances, boats, mobile homes, office furniture, toys, etc. In these fabricating industries, energy management is as important as it is in automobile manufacturing.

# Mechanics of Energy Conservation

One major automobile manufacturer has developed an Energy Index and Goals Program which may be applicable to any fabrication and assembling operation. The system calculates the total energy utilized per unit of output. Using the system, goals can be set and progress towards meeting these goals can be measured. Programs such as these, rely on energy conservation measures which can be enacted rapidly with little requirement for engineering and redesign. These measures include: reducing heat waste, better use of lighting facilities, more effective operation of heating and ventilating systems, improved process control, and better design and utilization of electrical equipment and systems.

The longer-run rearrangement or modernization of existing facilities offers additional major energy savings. Some of these measures which are relevant for all general manufacturing industries include:

- Enclosure of shipping docks and vestibules in lieu of large traffic doors. (Door heaters are generally ineffective and use large quantities of energy--usually natural gas which is in short supply.)
- Sizing of equipment for flexibility in turnarounds and shutdowns during low-or nonproductive periods where practical.
- Application of additional insulation, particularly on overheated exterior surfaces, outdoor heating ducts, condensate piping, etc.
- Reuse and/or recycling scrubber exhaust air.
- Recovery of heat and reuse of wasted process exhaust heat for heating combustion air, preheating the product and/or building heat. (Devices such as stationary and rotating air-to-air heat exchangers and passive heat pipes are available.)
- Application of capacitors at the load for power factor correction.

- Application of peak-demand controls for large blocks of electrical loads, gas-fired process heating equipment, etc.
- Application of monitoring and controls and/or the addition of energy and production measuring, monitoring, etc., capability to process computers.

# Short-Term Conservation Potential

The automotive industry estimates that for the short-term period of 1974 to 1978 (using 1972 as the base period), a reduction in energy consumption of about 10 percent per unit of output can be achieved by conservation measures and administrative controls. Major engineering and process changes to existing operations are not anticipated in the short term, especially for those sectors of the industry that use energy as a raw material.

#### INDUSTRIAL BOILERS

Over 20 percent of all the energy consumed in the United States, or 15 quadrillion BTU's per year, is utilized in the form of process steam for industry. Since practically all of this steam is generated in industrial direct-fired boilers, the opportunities for energy conservation in boilers merit special attention.

An analysis of boiler sales data by the American Boiler Manufacturers Association shows the following breakdown of boiler users by industry:

Industry	Percent of Use
Chemical and Allied Products Paper and Allied Products Petroleum Refining and Related Industries Food and Kindred Products Electric UtilityNongenerating Use Miscellaneous Manufacturing Primary Metal Industries Textile Mill Products Transportation Equipment Lumber and Wood Products Rubber Products	19.0% 17.5% 13.3% 12.3% 9.4% 8.0% 6.0% 5.0% 4.5% 3.0% 2.0%
Total	100.0%

This tabulation reveals the industries in which energy conservation through improved boiler operation can be most significant. Reduction of input energy used for steam or hot water generation can be achieved by instituting or improving the following processes or controls.

- Loading Parameters Versus Boilers in Operation: An analysis of steam flow meters should be made in relation to the total boiler plant output and individual unit output. Operating schedules can then be arranged so that output of boilers on the line matches steam demand, as closely as possible, and the number of units fired at less than optimum rate is minimized.
- Regulation of Operating Cycles: Where possible, loads should be scheduled or adjusted so that boiler operation at the optimum rate can be achieved and on/off cyclic operation is minimized
- Combustion Rate Control: Use of combustion rate control equipment should be reviewed so that input rate tracks load demand, and on/off cyclic operation is reduced to an absolute minimum. This may require replacement or modernization of the combustion control system or readjustment to assure best operating conditions.
- Fuel Selection and Preparation: While the primary fuel used should be one recommended by the unit manufacturer for most efficient fuel utilization, consistent with emission requirements, due consideration should be given to the possible use of waste fuels as primary, alternate or supplemental fuels. The equipment used for preparation of fuel for burning needs careful study and checking for adequacy and adjustment. For example, liquid fuels should be at the correct preheat temperatures and correct atomizing pressures for optimum burning. Additional coal cleaning, sizing and pulverizing equipment, fuel pressure regulators and special facilities needed for waste fuels may be required.
- Fuel/Air Ratio Control: All modern boiler units in the size ranges discussed in this section are equipped with systems of integrated devices which automatically regulate the fuel and combustion air inputs to satisfy the rate of heat demand from the units. The selection of the particular type of systems listed below depends on an analysis of the system loading and operating characteristics. The following are systems from which selections may be made:
  - --On/Off System (not recommended for units in this class)
  - --Modulating Control System
  - -- Full Metering and Proportioning Control System.
- <u>Control of Auxiliary Systems</u>: Auxiliary systems and their maintenance procedures should be reviewed to be sure that items such as defective steam traps, poor lubrication, bad bearings and/or inoperative subsystems do not reduce the overall efficiency of operation.

- Water Treatment: Proper water treatment is necessary to minimize boiler outages, protect the unit and promote high heat transfer efficiency. If encrustations of scale are allowed to accumulate, efficiency can be drastically reduced. A qualified water consultant should be employed and his recommendations as to sampling procedure, fequency and quantity of treatment should be carefully followed.
- Maintenance Schedule and Records: Maintenance is the key to keeping a well designed and efficient system in peak operating condition. The maintenance schedule and appropriate check-off sheets and record keeping procedures must be reduced to writing. It is the management's responsibility to be absolutely sure this function is carried out. Record keeping is an important part of this operation and will enable supervising personnel to spot trends and offnormal conditions.

Consideration should also be given to equipment modification and/or replacement and to adding equipment to maximize operating efficiency. In the past, such changes may not have been economically justifiable but the current insecure fuel supply outlook and higher fuel costs necessitate complete reviews of operating economics. Items to be considered include, but are not limited to:

- Air heaters
- Economizers
- Fuel burning systems
- Combustion control systems
- Operating instrumentation
- Soot blowing equipment
- Feedwater systems
- Water treatment equipment
- Insulation to minimize losses
- Feasibility of unit replacement.

The best designed and maintained system is inadequate without well-trained operating personnel. Continuous operator training is essential to adjust for personnel turnover and to correct poor operating habits that may creep into a well planned system. Coupled with a system for inspection and supervision, this training will ensure that the steam generating units remain at peak operating efficiency.

The environmental impact of changes in fuel patterns has to be considered. When the fuel supply situation is such that fuel

switching is necessary, the consideration of cleanup equipment (e.g., scrubbers, mechanical collectors, electrostatic precipitators) may be required. Changes in  $NO_X$ ,  $SO_X$ , particulates and visible emissions should be considered as well as the problems of solid or liquid waste disposal from fuel burning.

Reduced emissions as a result of reduced fuel consumption and improved operating efficiency also needs to be "cranked into" this calculation. Trade-offs between solid waste pollution and air emissions should be considered when using waste fuels. Consideration of all these factors and implementation of the decisions will result in the best systems of operation from a fuel consumption point of view.

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# Appendices

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# United States Department of the Interior

OFFICE OF THE SECRETARY WASHINGTON, D.C. 20240

In Reply Refer To: AS-EM

July 23, 1973

Dear Mr. True:

In his energy statement of June 29, the President announced additional steps being taken to conserve America's fuel supplies and their use, and called upon private industry to respond to the energy conservation directives with all the imagination and resourcefulness that has made this Nation the richest on earth.

In December 1972, the National Petroleum Council submitted to me a comprehensive summary report on "U.S. Energy Outlook," the supporting detailed task force reports being now received for each fuel as completed. The results of this exhaustive work done by the energy industries has been of major value to the Department and other agencies of Government, shedding considerable light on the U.S. fuel supply situation in particular.

In order to further assist us in assessing the patterns of future U.S. energy use, the National Petroleum Council is requested to conduct a study which would analyze and report on the possibilities for energy conservation in the United States and the impact of such measures on the future energy posture of the Nation.

You are requested to submit a progress report by January 1, 1974.

Sincerely yours,

Secretary of the Interior

Mr. H. A. True, Jr. Chairman National Petroleum Council 1625 K Street, N. W. Washington, D. C. 20006



The following industry representatives have participated in this Energy Conservation Study.

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